Using SCADA Data, Field Studies, and Real-Time Modeling to Calibrate Flint's Hydraulic Model

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Outline

- Background and purpose
- Approach to model updates and calibration
- Real-time modeling
- Applications and further work

General Background & Timeline

< 2014

- 1967-2014 Treated water purchased from Detroit
- Back up source was Flint WTP with Flint River
- Population 200,000 (1960) 100,000 (2010)
- 2013 approved plan to switch to KWA

April 2014

- **Switch to Flint River**
- No corrosion control applied
- Under LCR, MDEQ saw Flint WTP as a new system needing two rounds of successive rounds of LCR sampling
- Immediate aesthetic complaints

Aug-Dec 2014

- Elevated DBPs caused Stage 2 DBPR Operation Evaluation Level Action/report
- TTHM MCL exceedances in Dec, Mar, June
- Detection of E. coli and low chlorine residual resulted in an acute and monthly TCR violation & boil water advisory

Feb-July 2015

- Flint citizen and Virginia Tech found high lead levels in home
- EPA Region 5 contacted & initiated investigation
- EPA internal memo leaded publicly

October 2015

- **Flint reconnects to Detroit's water system, but the pipes have already been damaged**

January 2016

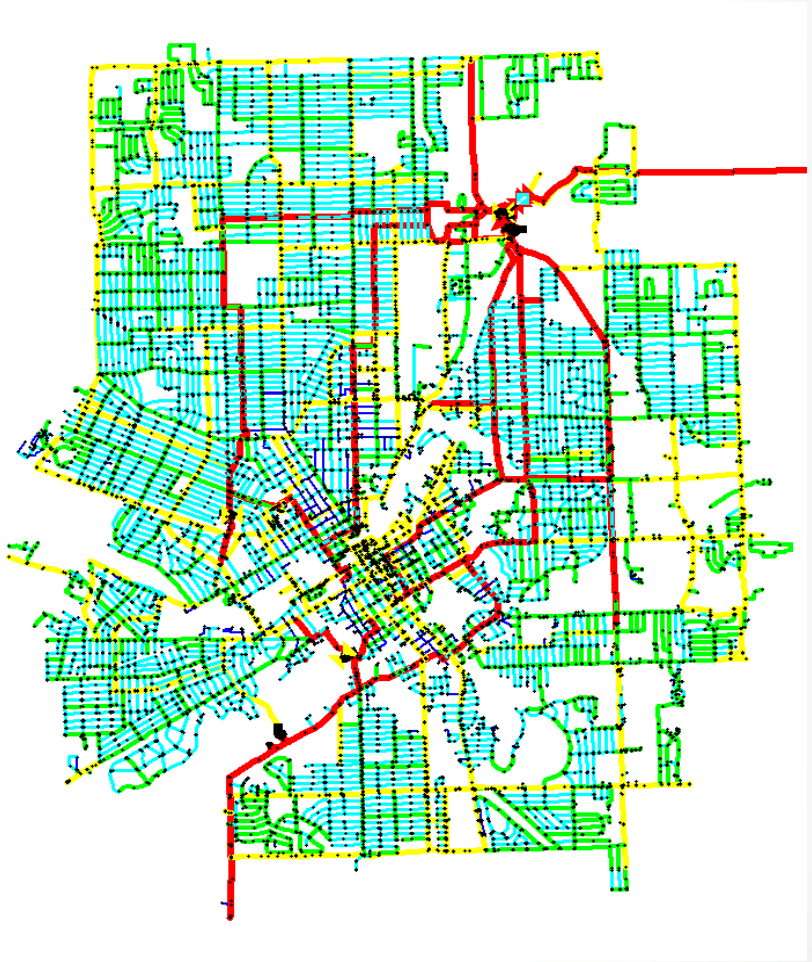
- US declared Federal State of Emergency
- EPA declared Safe Drinking Water Act Emergency Order
- **EPA Tech Support:**
- Improved LCR sampling
- Residual sampling & flushing
- Addition of orthophosphate caustic & chlorine
- Corrosion control studies

Today

- City of Flint announced intention to stay with Detroit water with County as back up
- Ongoing work

Modeling to Support City of Flint

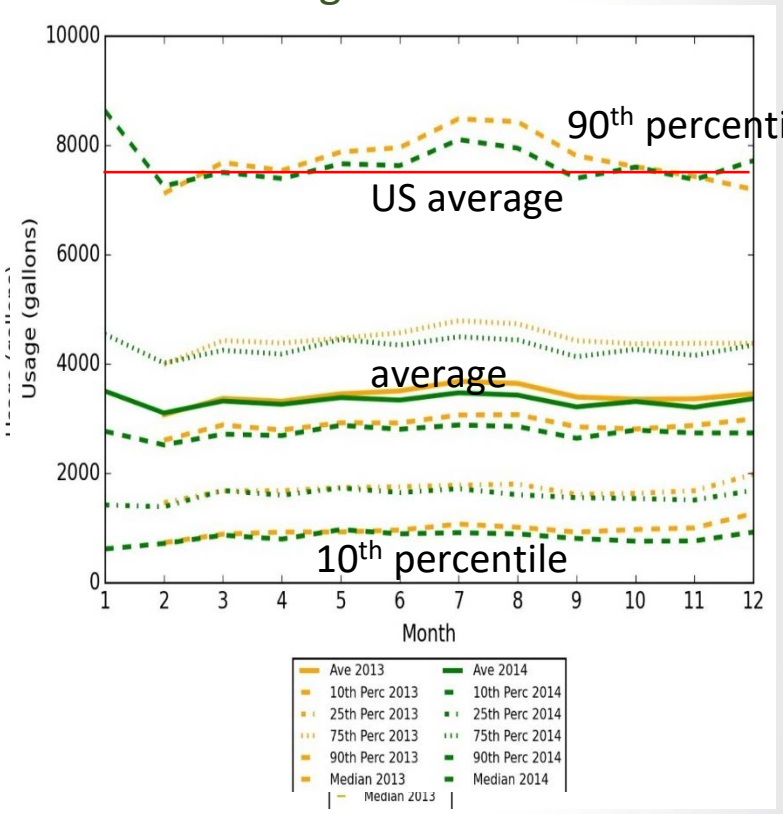
- What are the flow patterns?
- What is the residence time?
- How has customer usage changed?
- Can sampling locations be improved?
- Can the distribution system operation be optimized?
- How will new water source & operating rules affect pressure and water quality?
- How can common summer water quality problems be mitigated?
- What are the effects of oversized infrastructure on water quality?



Challenges

- Oversized and aging infrastructure
- Low & variable customer usage
- High percentage of unaccounted for water
- Changing system operations to improve water quality conditions
  - Chemical feed additions
  - Cycling of tanks
- Limited ability to do field tests because of focus on restoring stability of pipe internal surfaces

Water Usage Data 2013-2014

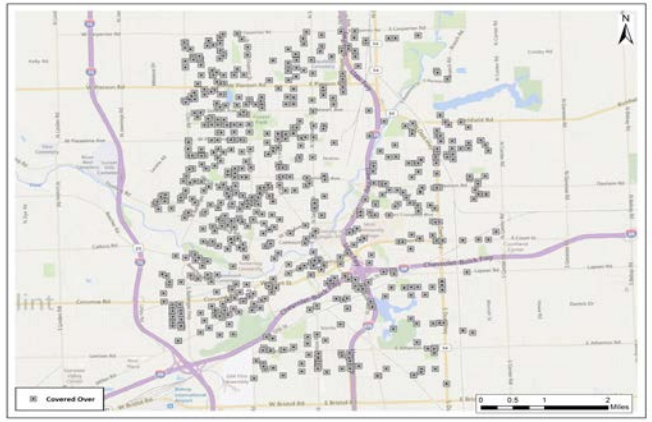


Approach to Model Improvement

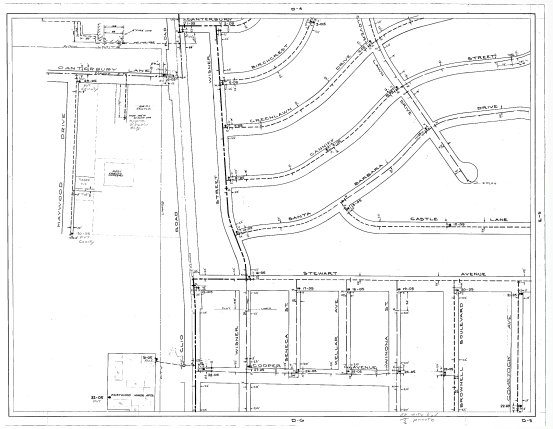
- Data collection
- Infrastructure & operations updates
- Customer demand updates
- Implementation of RTX:LINK (access to real-time SCADA)
- Integration of model, SCADA & GIS
- Field data collection (flow & pressure monitoring)
- Model calibration
- Model accuracy assessment
- Real-time modeling
- Scenario management (versions of model for specified applications)

Data Collection

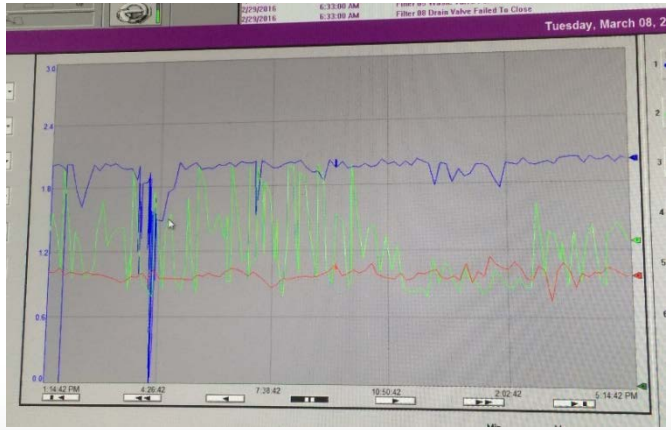
- Hydraulic model
- GIS layers & maps
- Info on operations
- Valve study data
- SCADA data
- Customer billing data
- Design diagrams
- Chlorine addition
- Automated flushing



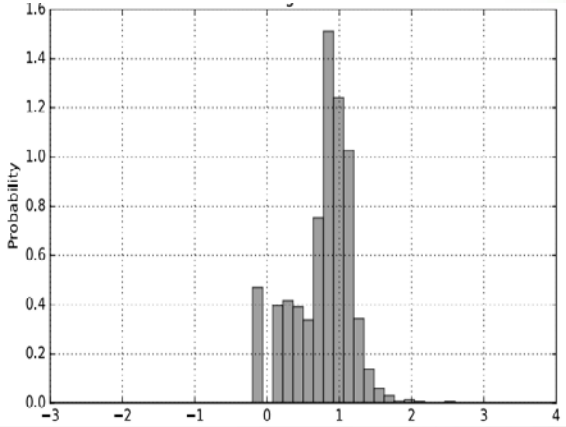
Covered Over Valves



Piping Diagrams



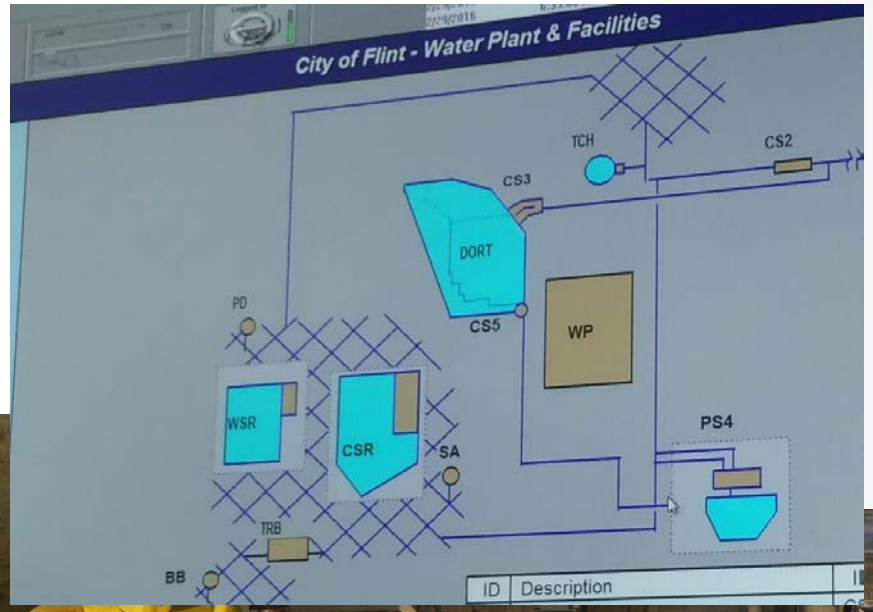
Chlorine SCADA Data



Usage Data

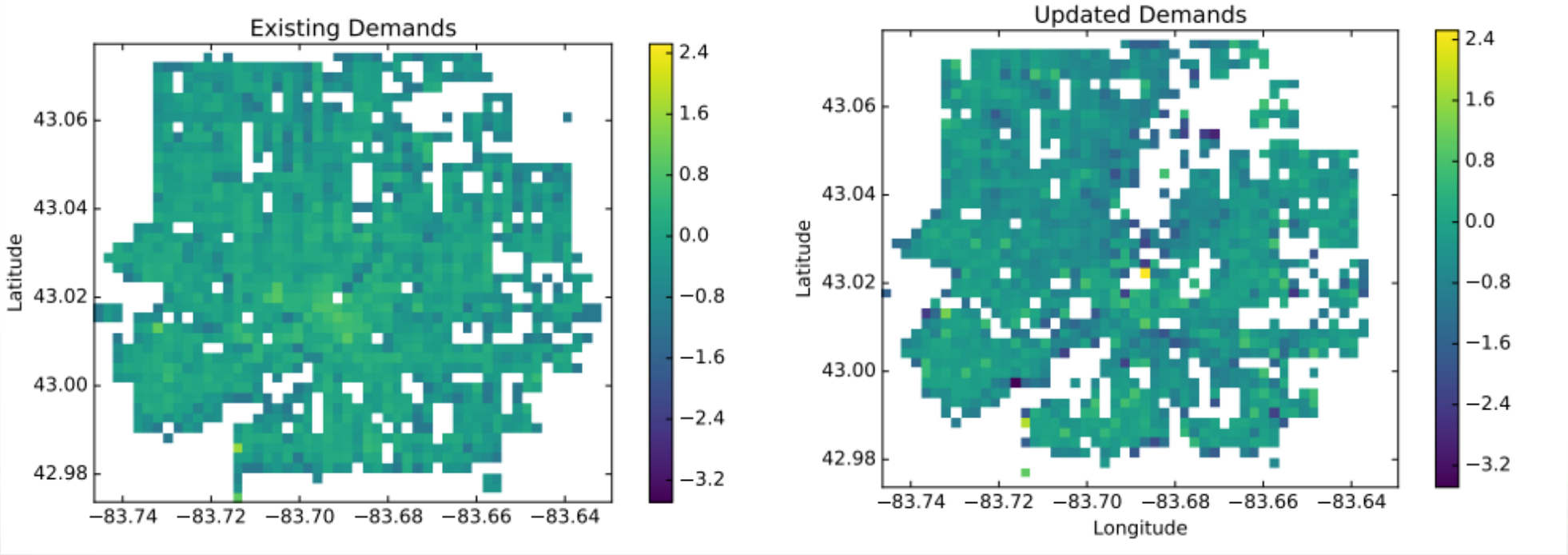
Infrastructure & Operations Updates

- Visited facilities, recorded diameter & lengths of pipes, type & characteristics of pumps
- Replaced flow control & other model valving with actual installed valve type, size, & characteristics
- Updated pump characteristic curves to match manufacturer
- Changed node elevations to match USGS/NED datasets

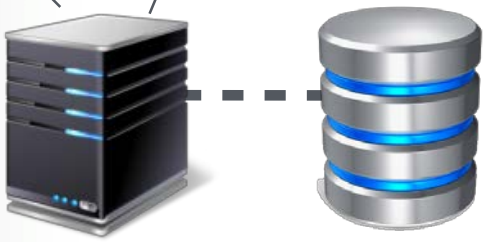


Customer Demand Updates

- Created database of 2013-16 billed water usage
- Using nearest neighbor GIS tool, updated base demands at each node
- Spatial changes from existing model to updated model shown below

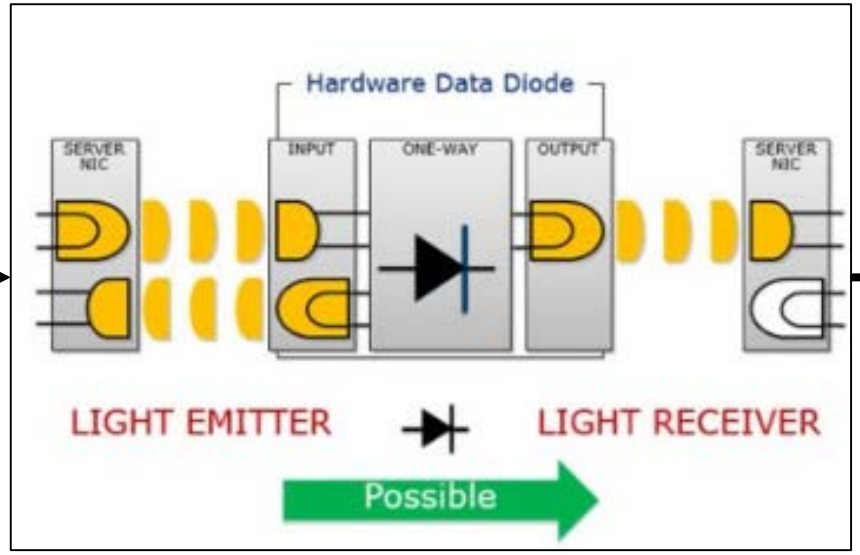


Secure Data Access RTX:LINK



SCADA Historian

RTX:LINK
(Raspberry Pi device)

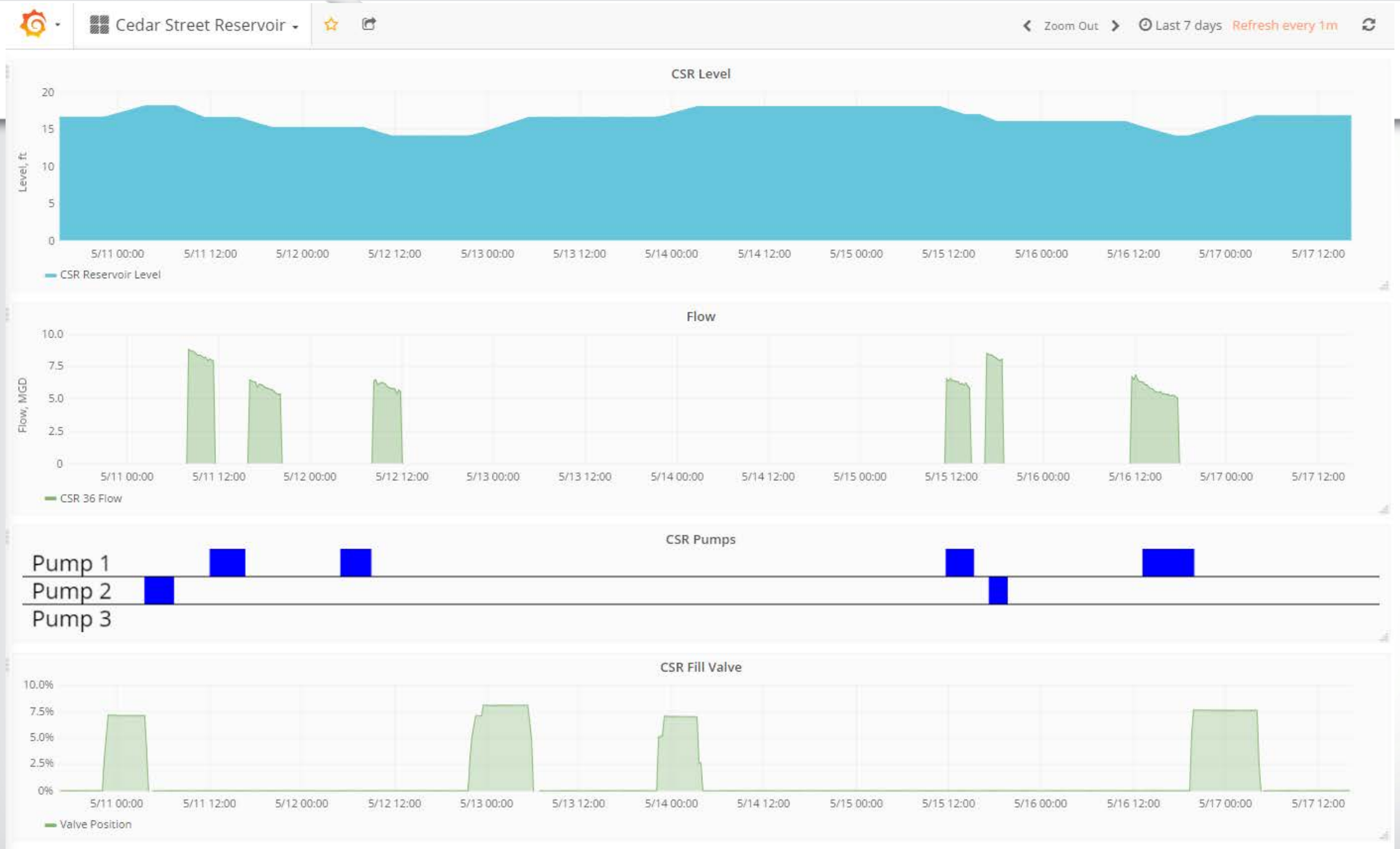


One-way Data Diode

Cloud-based
Real-Time Analytics
Dashboards

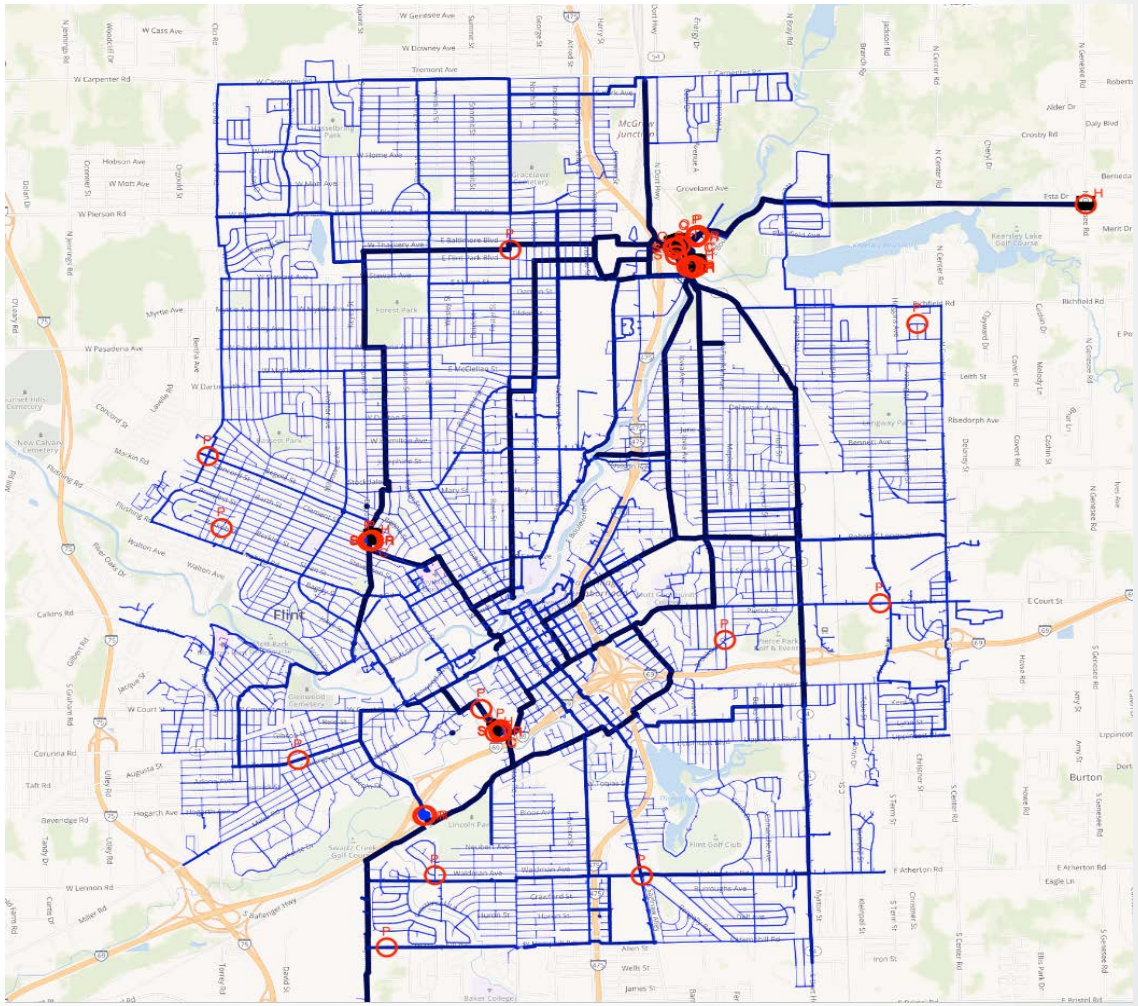
Phone

Laptop, tablet


Cedar Street Reservoir
Zoom Out
Last 7 days
Refresh every 1m
CSR Level
Level, ft
20
15
10
5
0
5/11 00:00
5/11 12:00
5/12 00:00
5/12 12:00
5/13 00:00
5/13 12:00
5/14 00:00
5/14 12:00
5/15 00:00
5/15 12:00
5/16 00:00
5/16 12:00
5/17 00:00
5/17 12:00
CSR Reservoir Level
Flow
Flow, MGD
10.0
7.5
5.0
2.5
0
CSR 36 Flow
CSR Pumps
Pump 1
Pump 2
Pump 3
CSR Fill Valve
10.0%
7.5%
5.0%
2.5%
0%
Valve Position

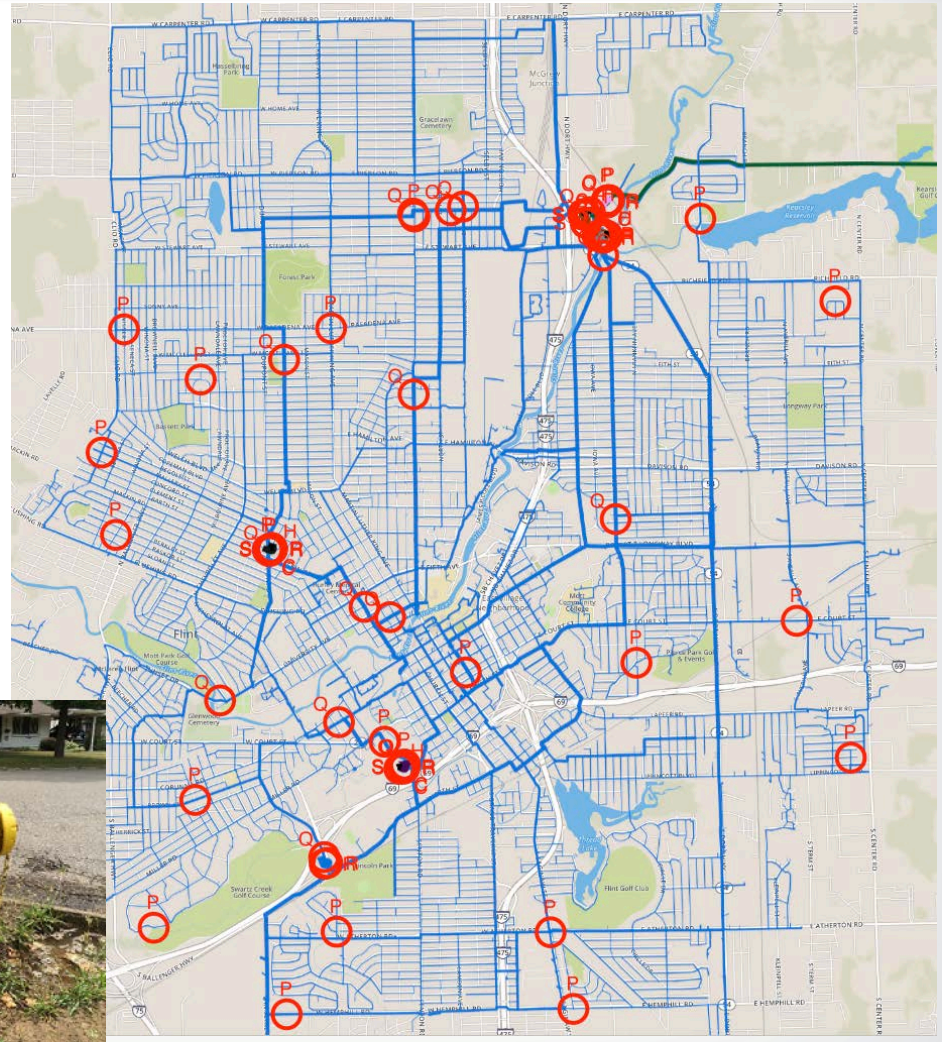
Integration of Model, SCADA & GIS

- Field data measured at entrance to system, treatment plant, tanks/reservoirs, pump stations
- Data in form of pump status, valve position, flow, tank level, pressure, chlorine residual, turbidity
- Pump status and valve position used to define operations in model
- Pressure head at entrance to system used to define model boundary condition
- Historical Simulation driven by CitiLogics Polaris™ with EPANET-RTX engine



Field Data Collection

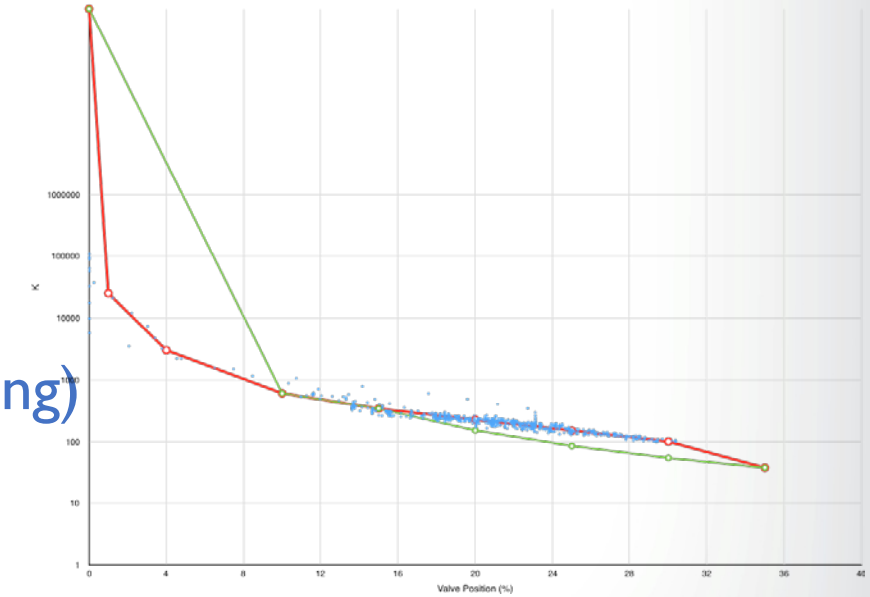
- Pressure loggers
  - 14 loggers installed on hydrants
  - July – October 2016 – 2-8 weeks
- Flow meters
  - 8 flow meters installed by HydroMax
  - January 2017 – 2 weeks
- Fire flow tests & pressure monitoring (Arcadis)
  - 30 pressure loggers
  - 7 flow tests
  - May 2017 – 1 week



Model Calibration

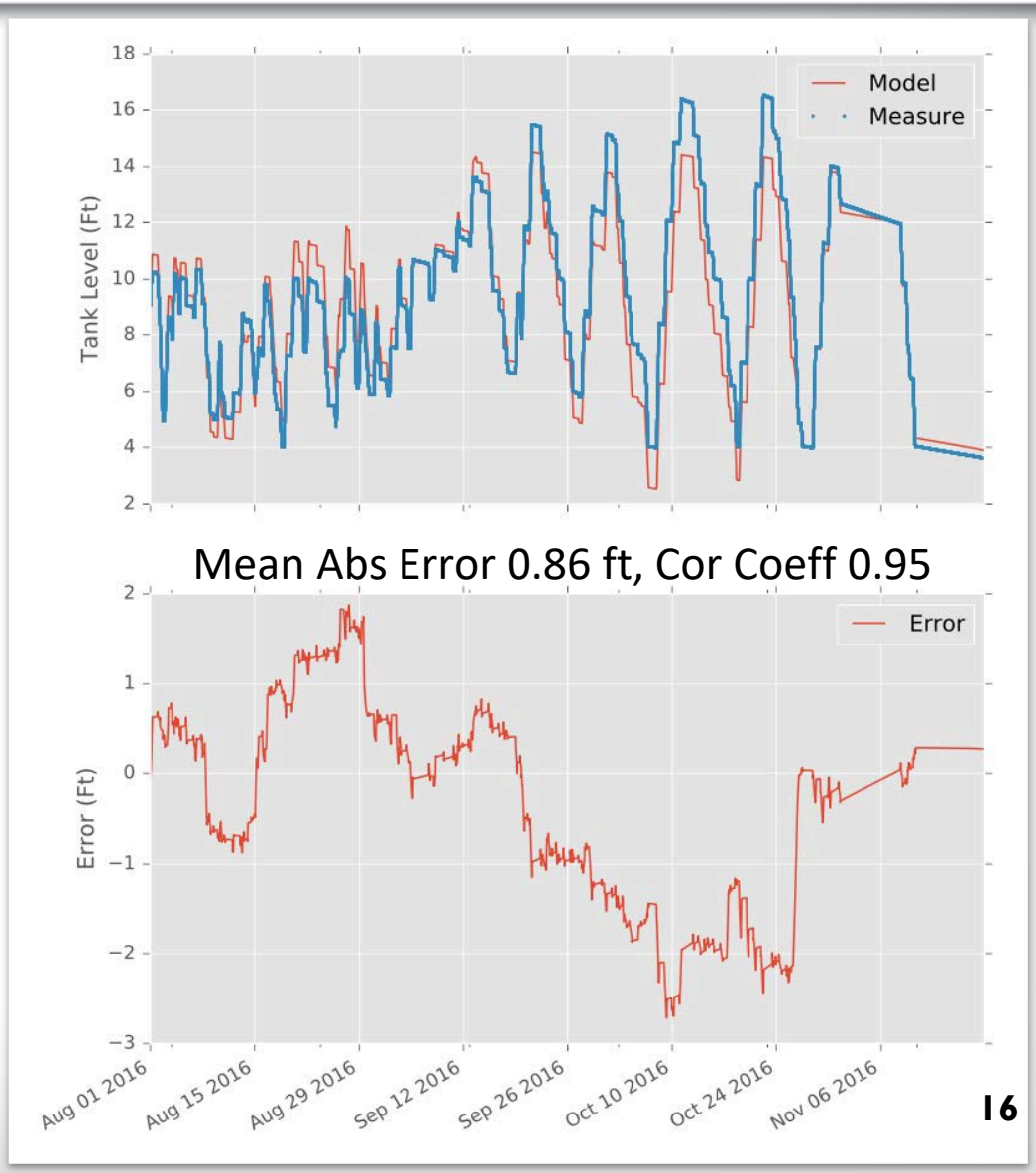
- Initial calibration adjusted following parameters
  - Valve loss curves (loss coefficient (K) vs. % open)
  - Pump head-discharge curves
- Additional calibration based on hydraulic grade data
  - Pipe roughness factors
- Water quality calibration using residual samples (ongoing)
  - Bulk and wall decay factors

CS2 Butterfly Valve
Head Loss Characteristics



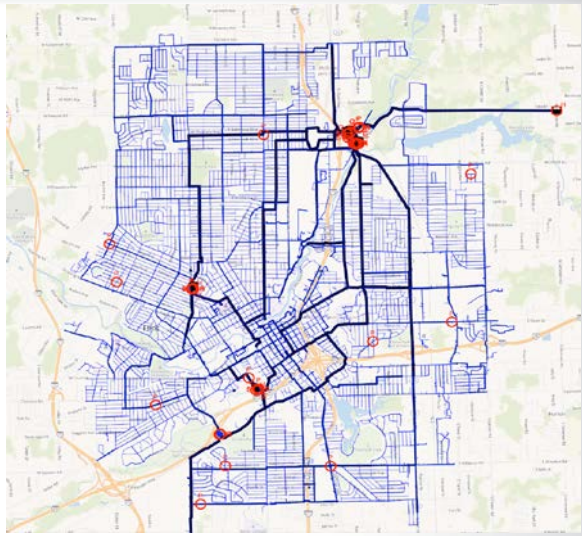
Model Accuracy Assessment

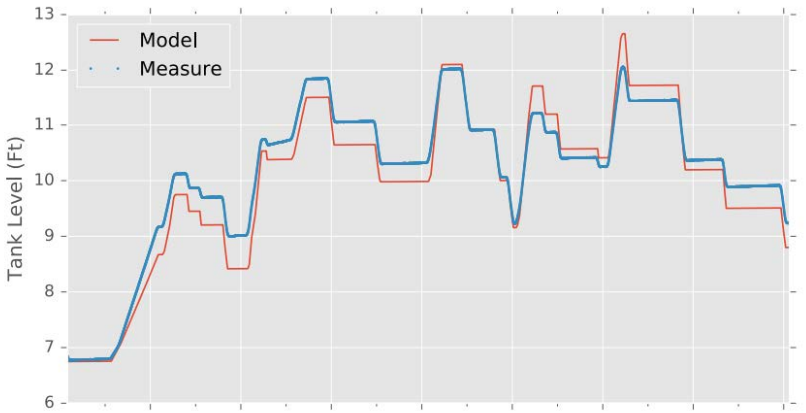
- Accuracy assessment
  - SCADA & pressure logger data
  - Aug-Nov 2016
  - Rigorous 16 week continuous comparison
    - Distinct operational modes
    - Long compared to industry standards
- Model results compared to SCADA-measured
  - HGL / pressure (psi)
  - Flow (gpm)
  - Tank levels (ft)
  - System demand (gpm)



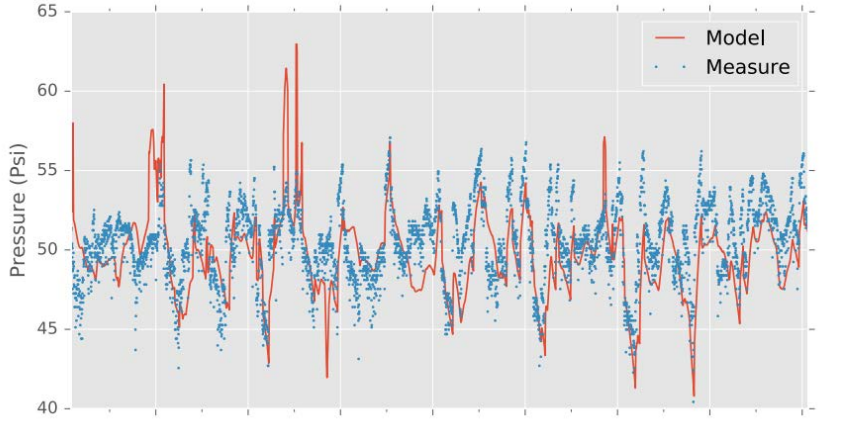
Accuracy Assessment Summary

- Distribution tank levels have mean error of 1.25 ft
- Distribution pressures have mean error of 1.8 psi
- Source, pump station, and tank flows have a mean error of 270 gpm
- Calibration of C factors indicated by grade differences

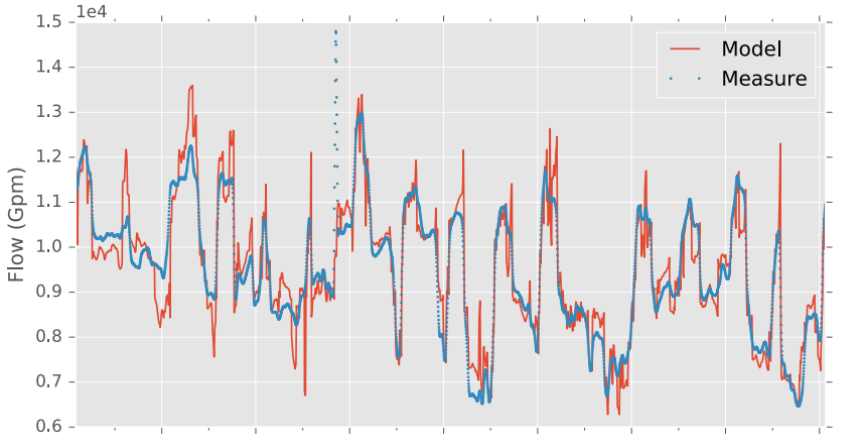




Tank Levels (ft)



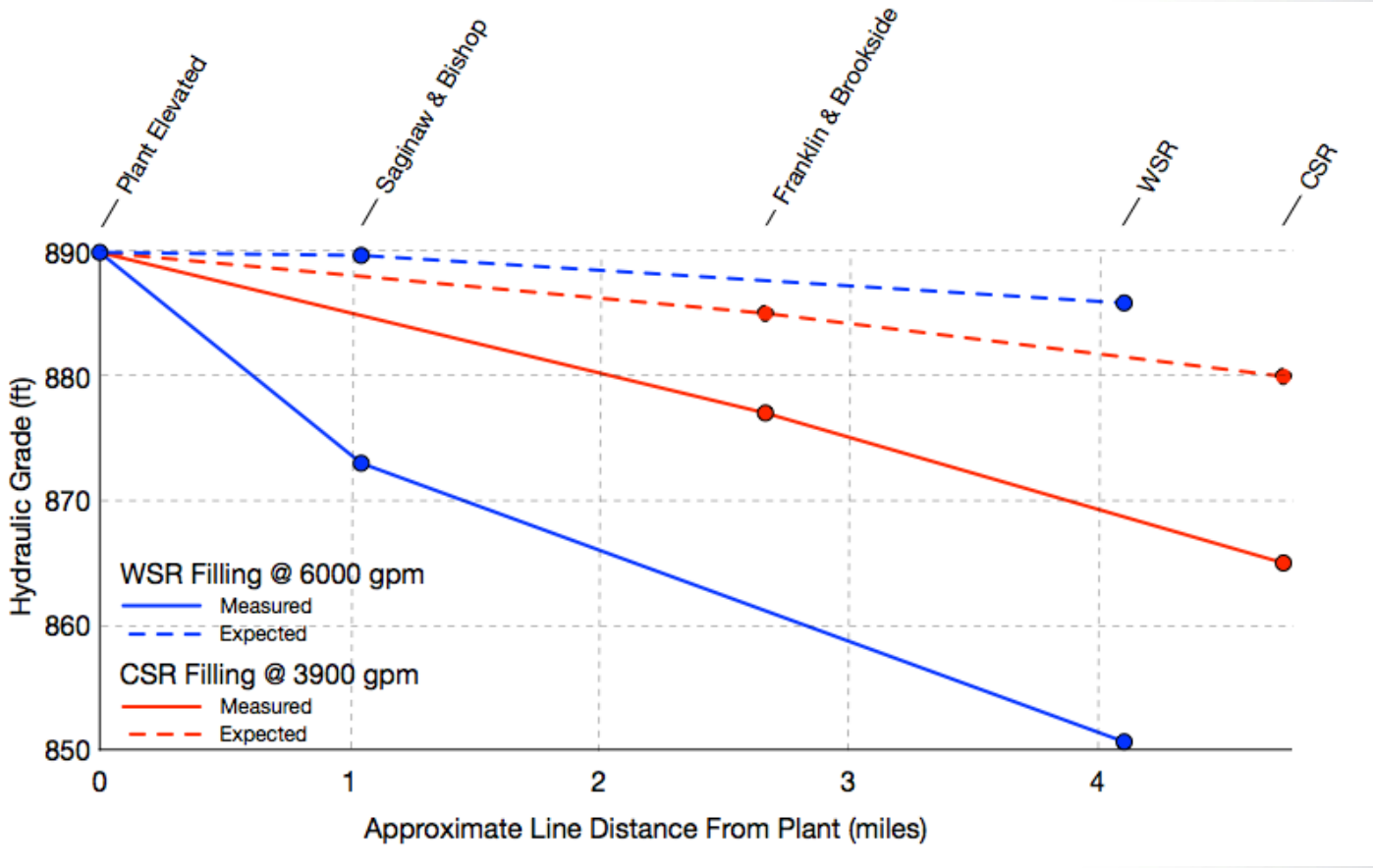
Pressure (psi)



Flow (gpm)

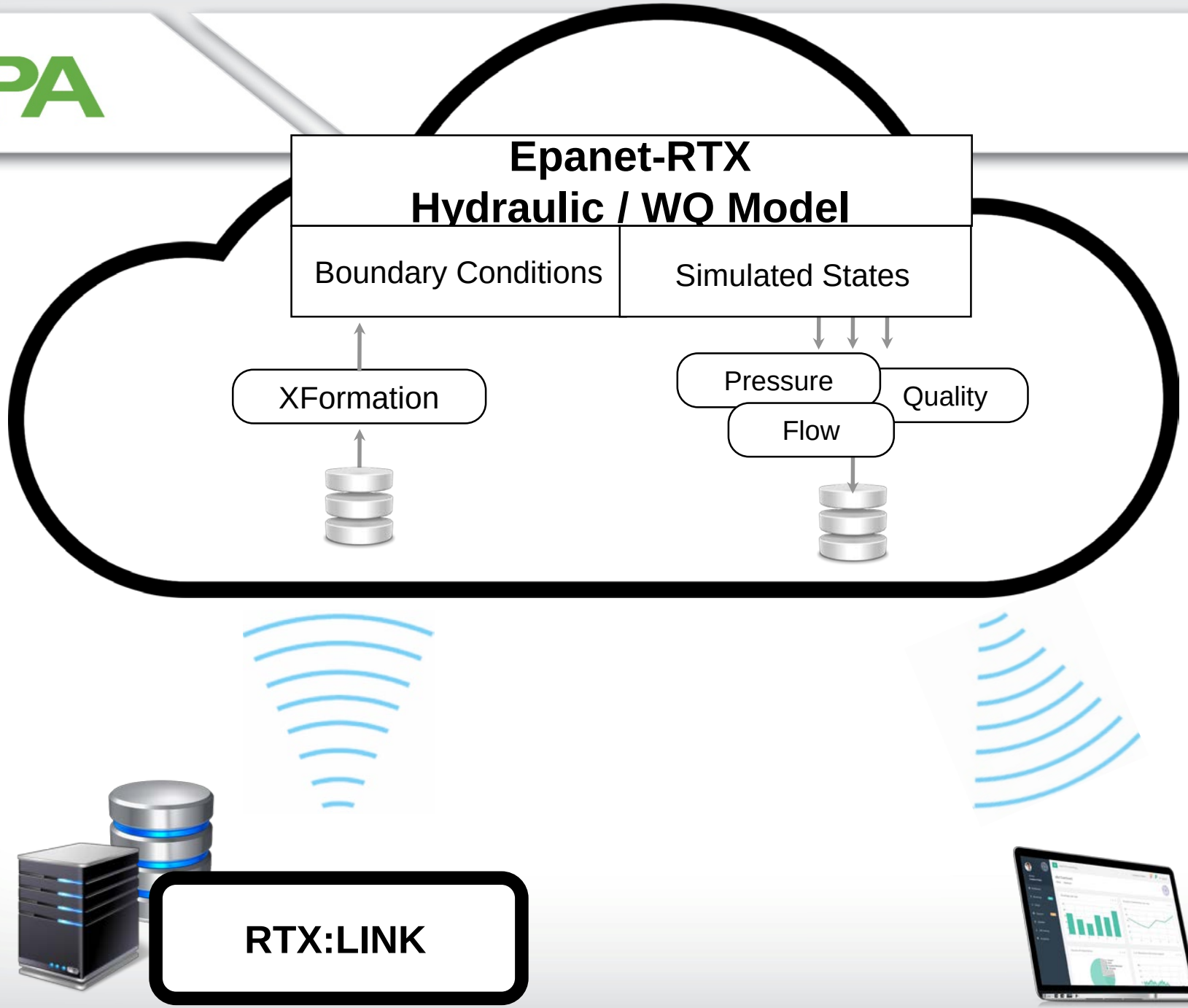
C Factor Calibration

- Severe errors in grade between plant and reservoir boundaries
- Grade errors amplified when reservoirs are filling (4000-6000 gpm)
- Measured head loss exceeded modeled from 2.5x to10x
- Calibration of C factors was implemented to correct grade differences
- Severe reductions in C factors were required in multiple transmission mains (C=30)
- Low distribution main C-factors have been confirmed by preliminary tests
- Transmission main tests proposed



Real-Time State Estimation

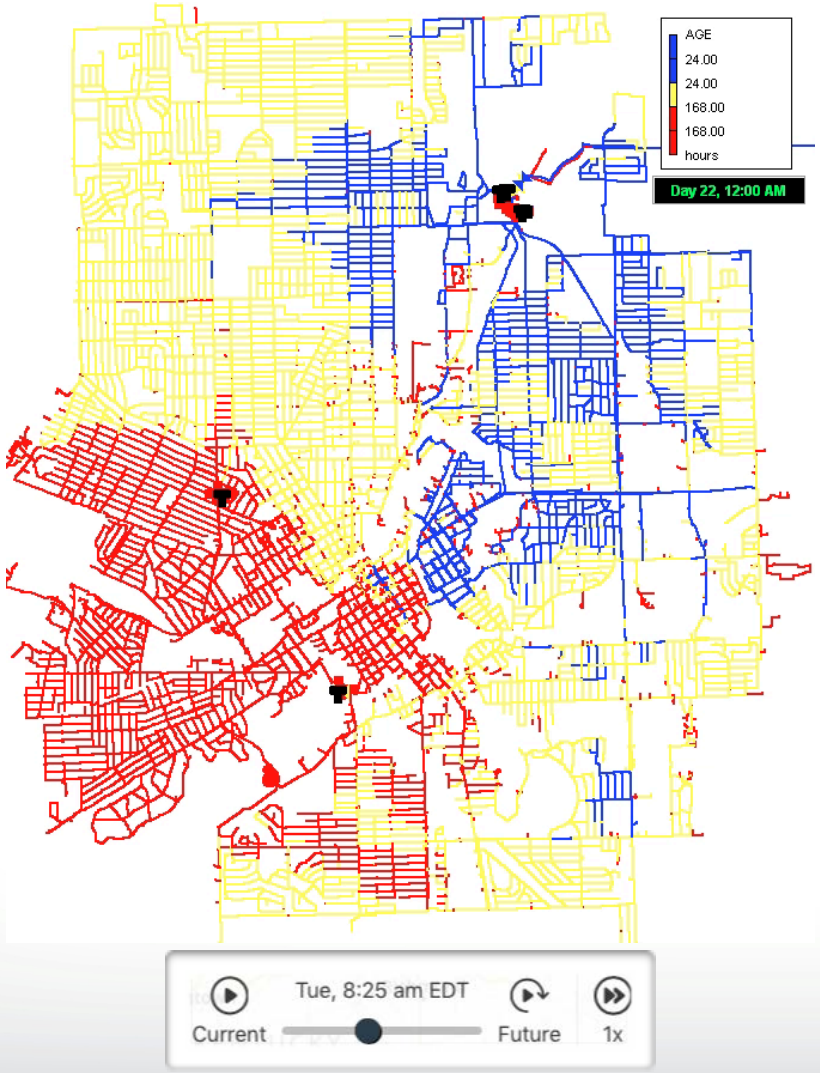
- Integration of network hydraulic and water quality models with on-line operational data streams
- Automated and continuous capability to simulate current and historical system states
- Data-driven diurnal demand curves and pump/valve statuses and settings.
- CitiLogics Polaris™ with EPANET-RTX engine
  - Maintains connection to SCADA & other data (e.g., flow meters)
  - Sanitizes / filters raw process data
  - Runs Hydraulic/WQ Model continuously
  - Stores results in efficient time series database
  - Leverages real-time user applications and dashboards



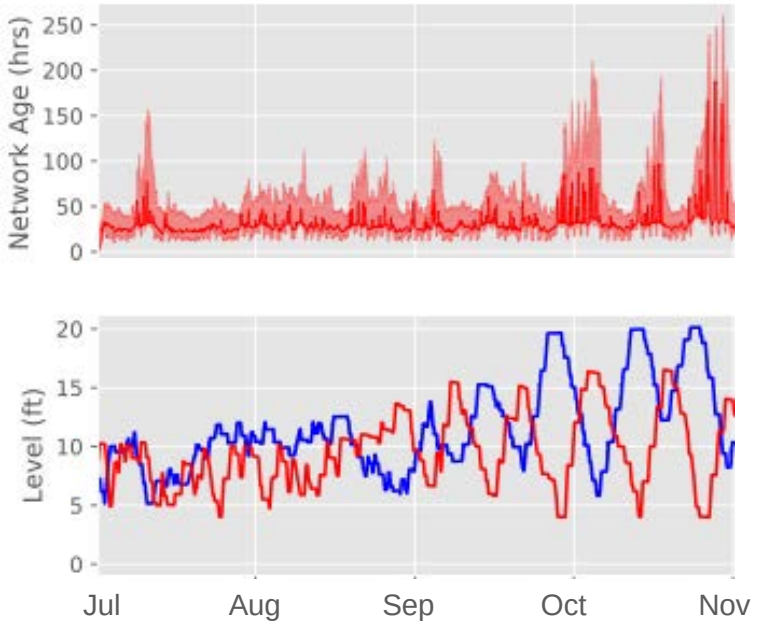
Polaris Real-time State Dashboard

Real-time Water Age Dashboard

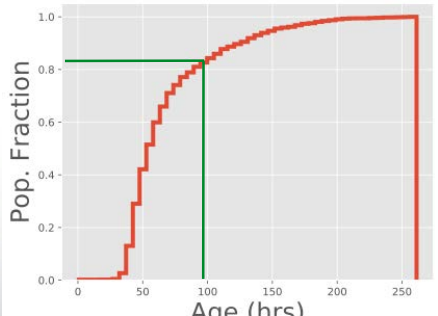
Day in Motion



4 Month History

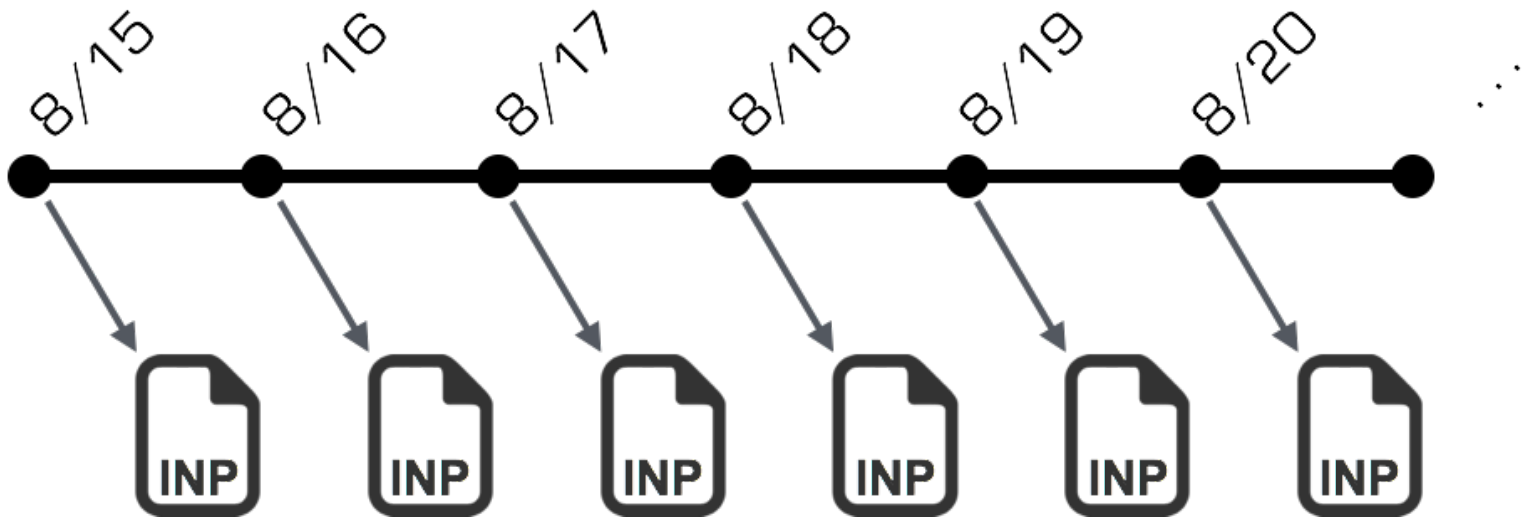


Day History



83

Snapshot Models & Calibration



- Download model + calibration files for any time period
- Incorporates all pump and valve operations, and demand curves, direct from SCADA
- Increase in calibration efficiency - eliminates all manual data processing for controls and demands
- Web service supports various automated tasks that rely on accurate operational models (emergency response, contaminant tracking, automated calibration, etc.)

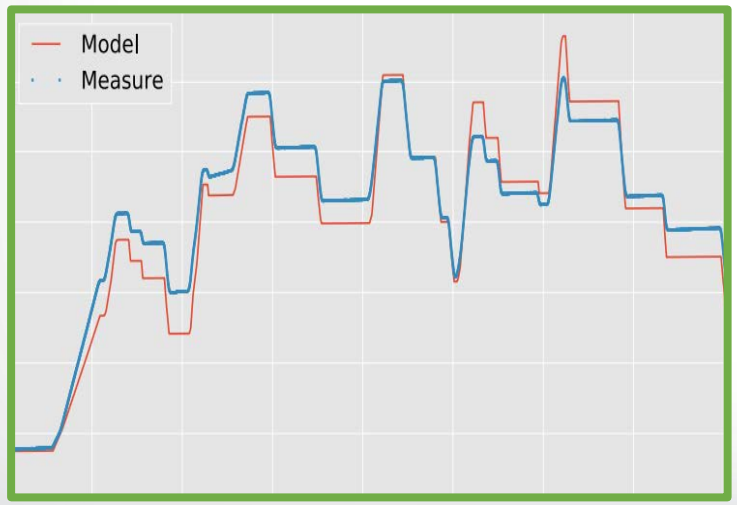
Scenario Analysis

- Understanding flow patterns and water age in system
  - Identifying low flow, low pressure and high water age zones
  - Determining how tank operations affect flow patterns and water age
  - Investigating benefits of DMA creation

- Optimizing operation of storage tanks
  - Reducing hydraulic connections between tanks
  - Scheduling pumps to reduce water age
  - Assessing chlorine addition at tanks
  - Investigating current and future storage needs

Conclusions

- RTX:LINK offers City of Flint operators real-time access to field data and important water quality metrics
- An updated and calibrated model is available for scenario analysis, planning and operations using WaterGEMS
- The Polaris real-time model is being utilized to provide up-to-date information on pressure and water age, and can be used to generate new models and assist with calibration



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